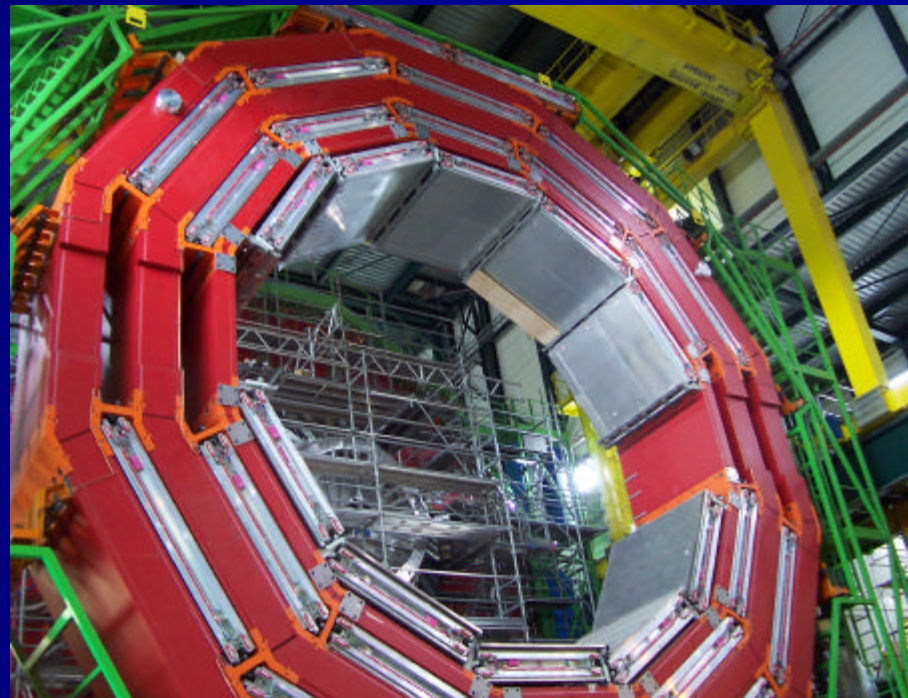




Physics with Muons in CMS – Potential and Challenges

PANIC05
Particles and Nuclei International
Conference Santa Fe, 2005



Kerstin Hoepfner, CERN & RWTH Aachen
On behalf of the CMS Muon collaboration
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The CMS Environment

- Compact Muon Solenoid (CMS) = one of 2 multipurpose experiments at the Large Hadron Collider

- pp Collisions with c.o.m.=14 TeV
- Design lumi $\mathcal{L}=10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
Start-up lumi $\mathcal{L}=10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Interaction Rate 40 MHz
→ collision every 25 ns

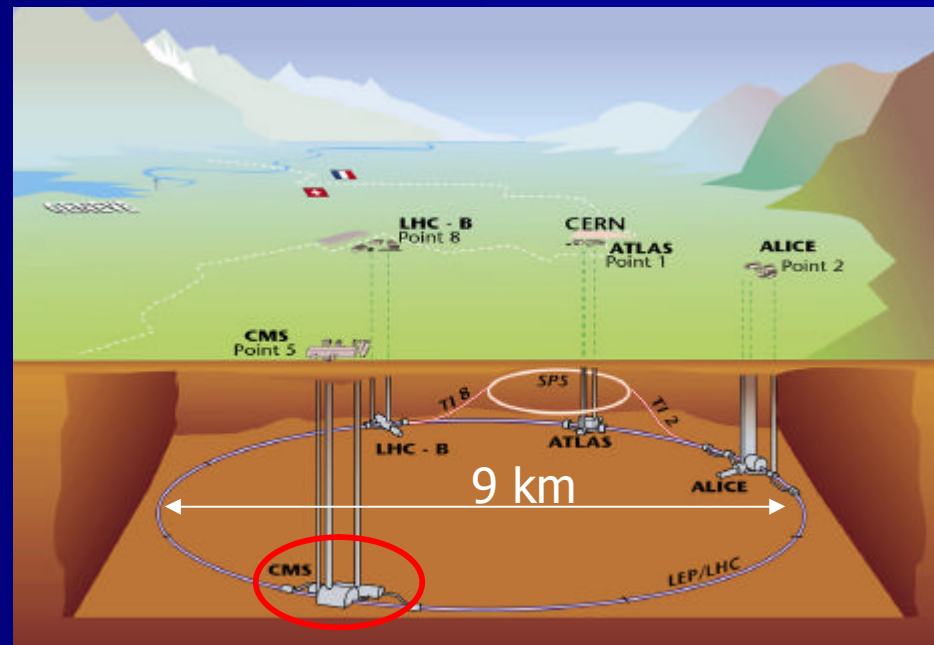
- **Consequences:**

- large background
- multiple interactions per BX

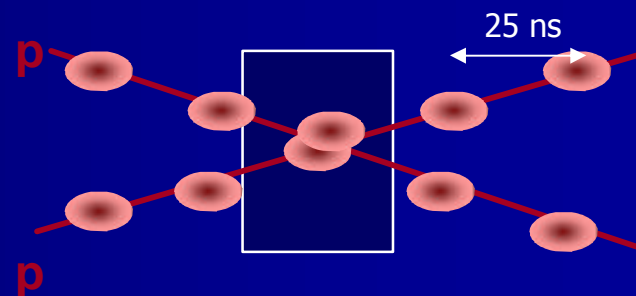


- **Impact on detector design**

- requires fast and radiation tolerant detectors with fine granularity
- reconstruction of track segments in muon system

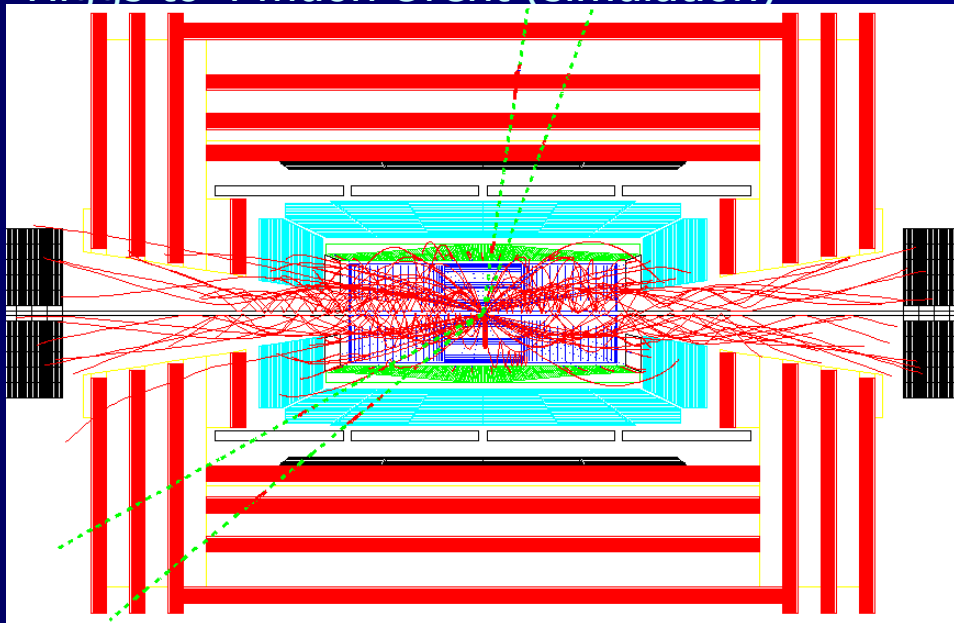


LHC now under construction
Scheduled Start-up 2007



- High p_T leptons (muons) in final state provide a clear signature
- Allows selection from background

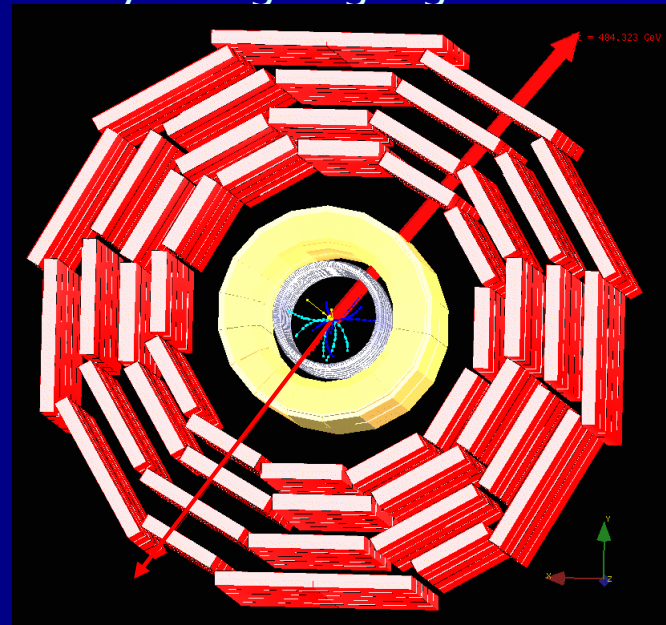
Higgs to 4 muon event (simulation)



Signal: $H \rightarrow ZZ^{(*)} \rightarrow \mu\mu\mu\mu$

Signature: 4 high p_T muons with $p_T > \sim 20$ GeV

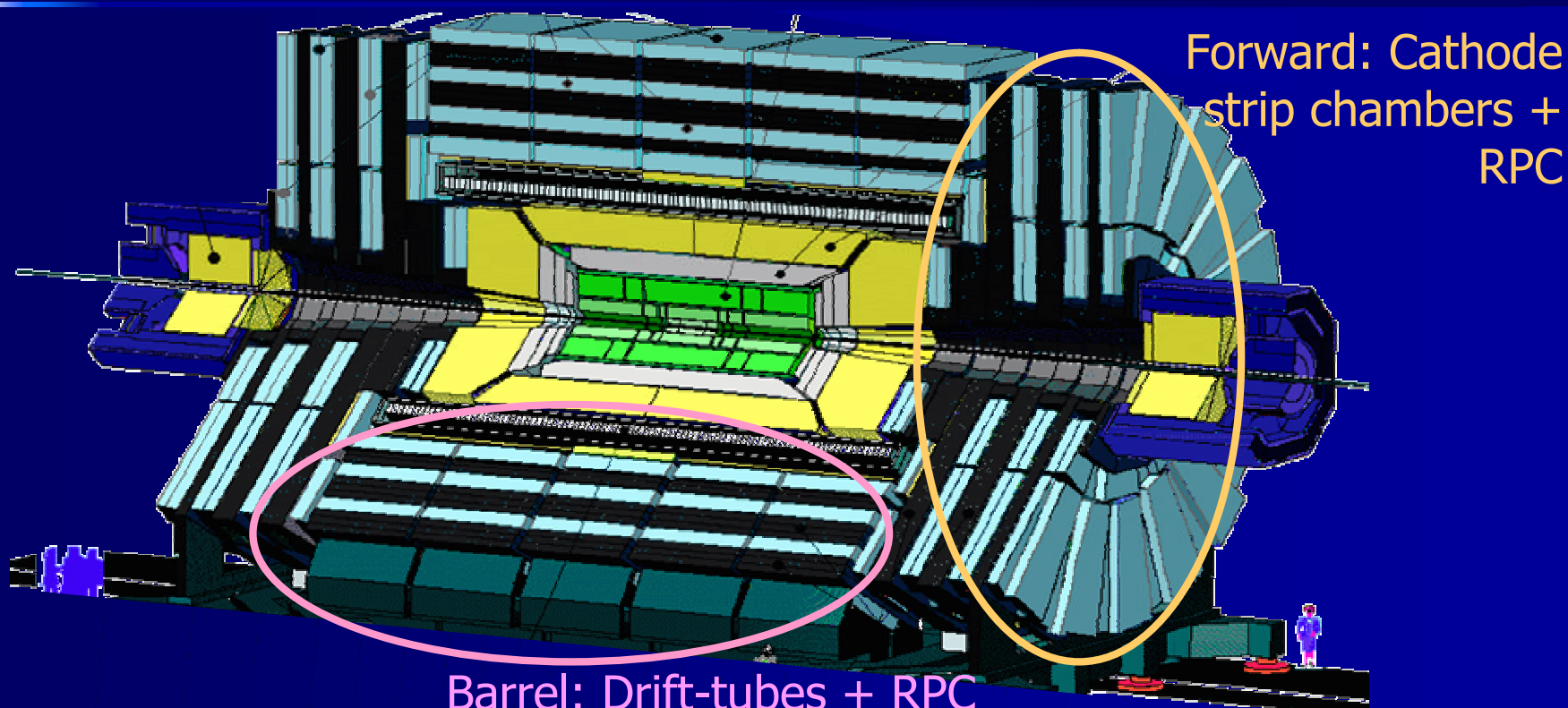
New particles beyond the SM, ex. heavy charged gauge boson W'



Signal: $W' \rightarrow \mu \nu_\mu$

Signature: muon with very high p_T and missing energy in opposite direction (in transverse plane, W' rest frame)

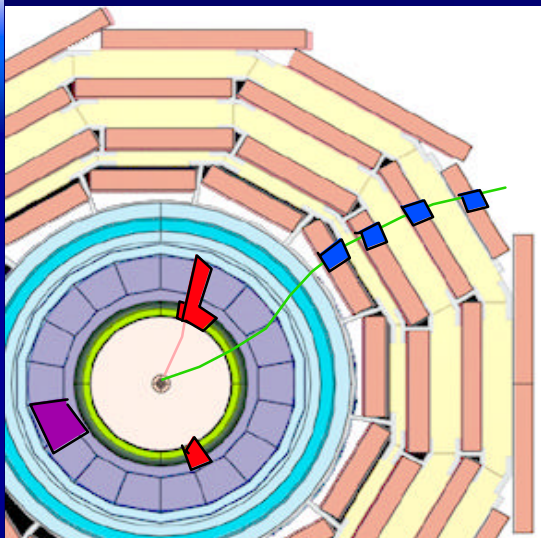
CMS Muon Detection System



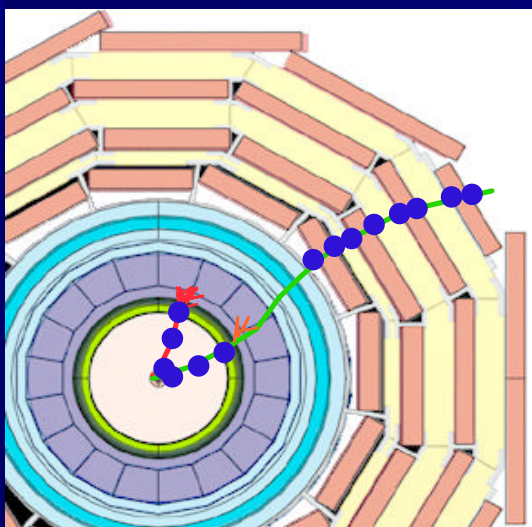
- Muon identification
- Charge assignment with 99% efficiency up to 7 TeV
- Muon Trigger
 - Unambiguous bunch-crossing (BX) identification
 - Trigger single and multi-muons with well determined p_T in range few GeV to TeV
- Precise Muon momentum measurement
 - Momentum resolution $dp_T/p_T = 1 - 1.5\%$ at $p_T = 10$ GeV
 - $dp_T/p_T = 6 - 17\%$ at $p_T = 1$ TeV



Event Selection



99.99 % rejected 0.01 %

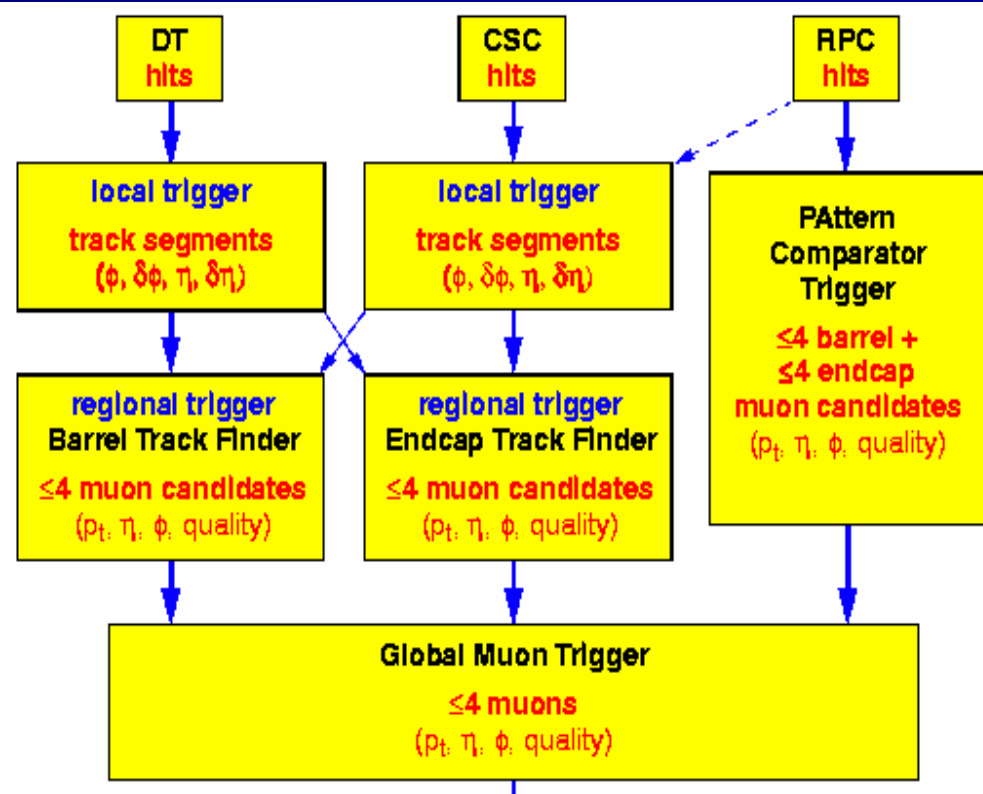


Level-1: Special processors

40 MHz system

Particle identification
electron, muon

Global muon trigger



High trigger
CPU farms

- Finer granularity, precise measurement
- Kinematic cuts
- Event reconstruction and analysis

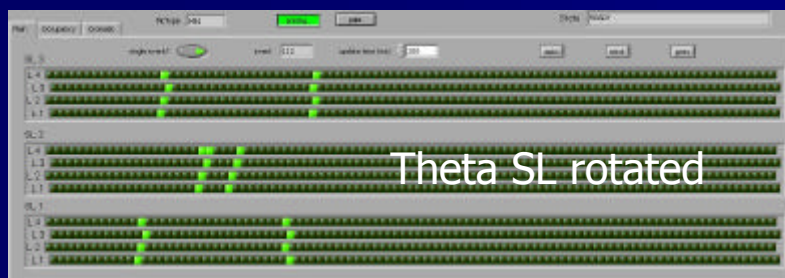
Barrel System



Drift-cells of $\sim 4 \times 1 \text{ cm}^2$

Gas: 85% Ar+15% CO₂ → 380 ns
max. drift time = 15 BX

Status & Performance



In 2 out of 5 wheels DT+RPC installed. Commissioning ongoing. First cosmic tracks seen.

Production sites for chambers (Aachen, Madrid, Padova, Torino) + readout electronics (Bologna, Padova, Madrid) + components (Protvino, Beijing). In total 210 DT chambers.

Status in fall 2005:

- Chamber production at the sites will be completed ~spring 2006. On-chamber electronics ~summer 2006.
- At Cern: chamber dressing, final testing with cosmics and coupling to barrel RPC.
- Installation mostly (barrel + forward) above ground. Lowering in 2006.
- DT+RPC packages for

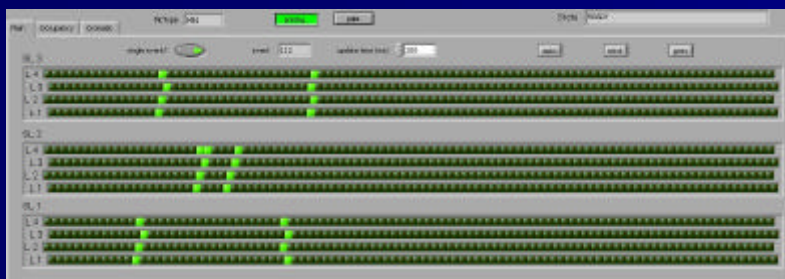
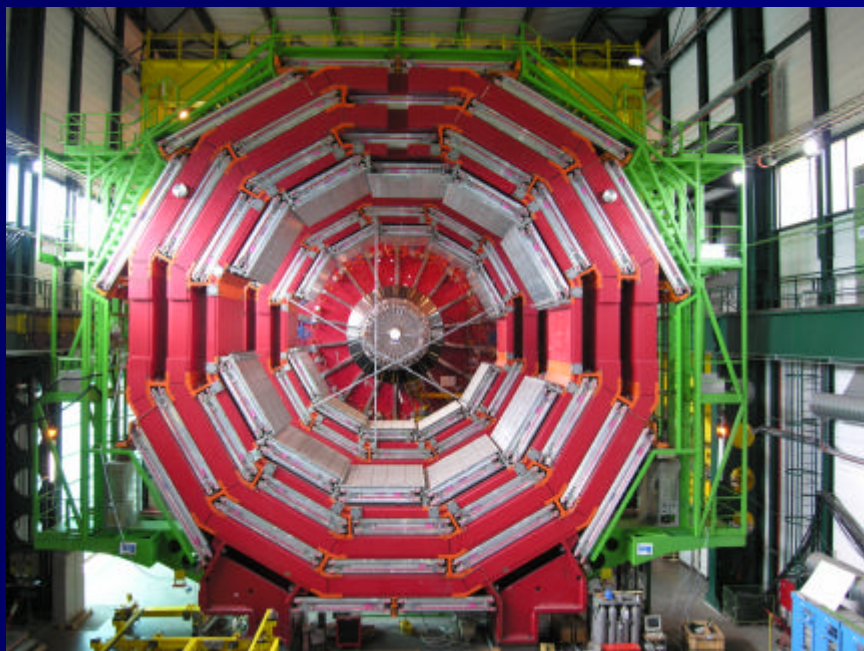
2 out of 5 wheels installed.



Status & Performance

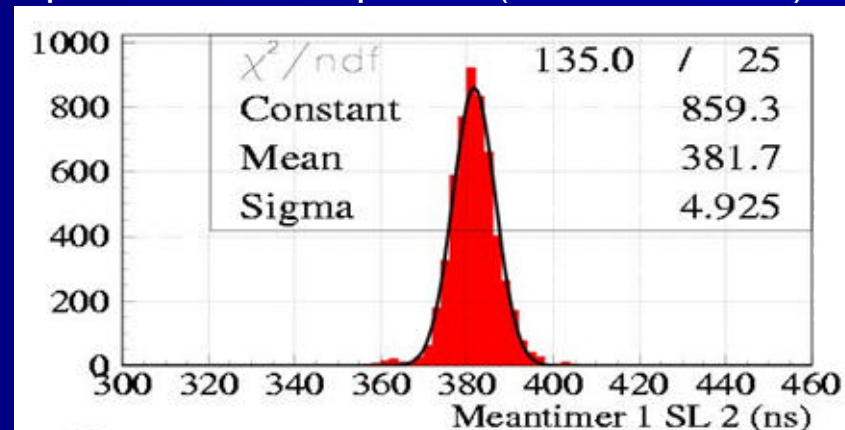
K. Hoepfner, CERN & RWTH Aachen

Physics with Muons in CMS - Potential and Challenges



In 2 out of 5 wheels DT+RPC installed. Commissioning ongoing. First cosmic tracks seen.

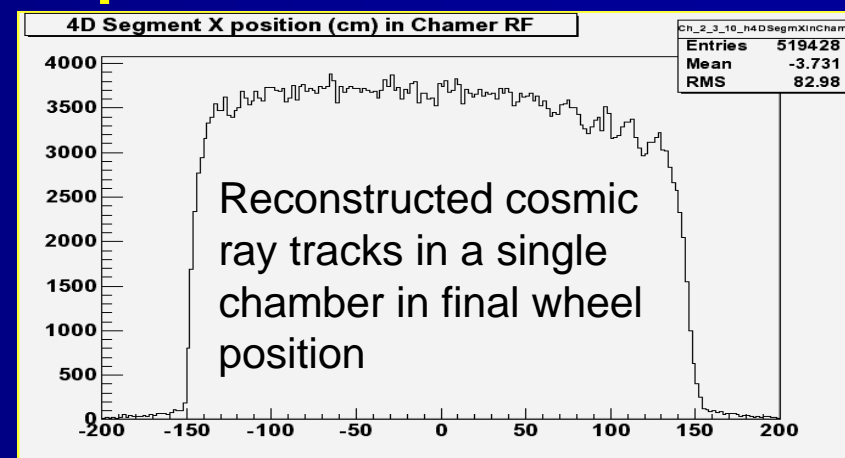
Spatial resolution per SL (Testbeam data)



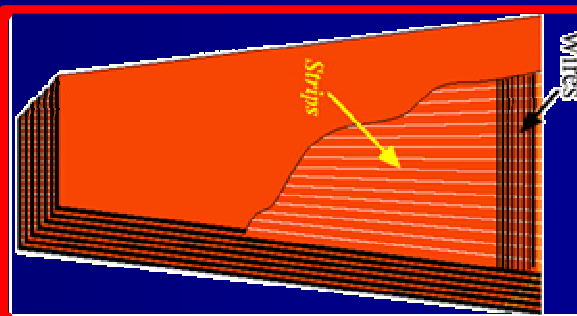
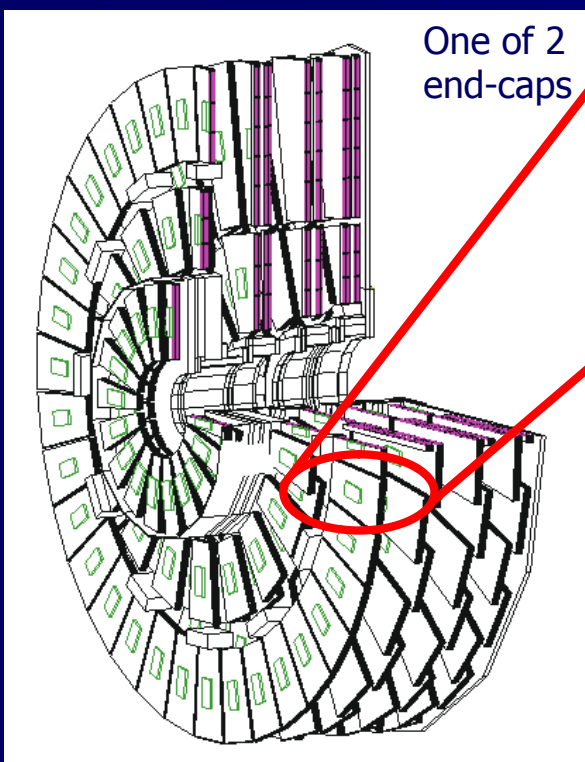
Resolution $\sim 220 \mu\text{m}$ per SL

Dead channels $\ll 1\%$

Performance according to expectation!



CSCs for Forward Muons



Wires orthogonal to **strips** (except for ME1/1 rotated 25° to compensate Lorentz Effect)

Anode wires = fast

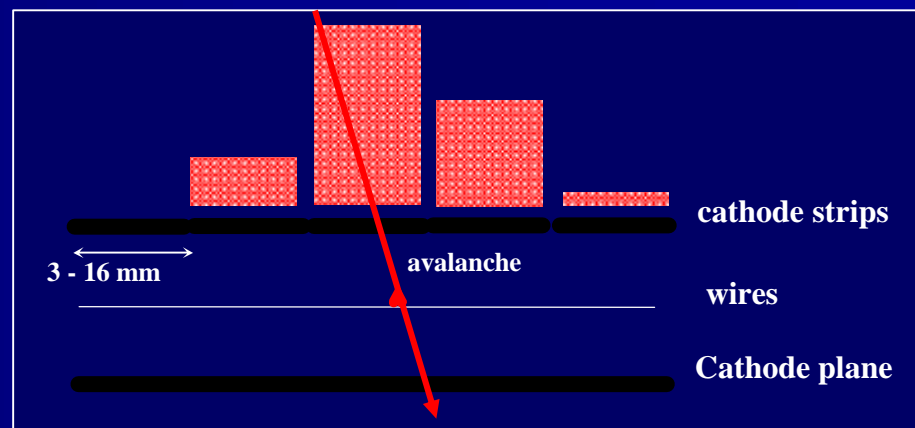
→ Precise timing measurement (BX) $\sim 4\text{-}5$ ns

Cathode strips = precise

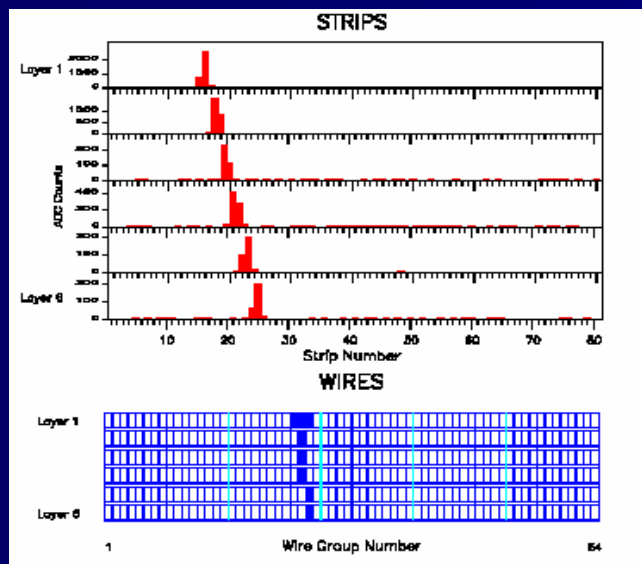
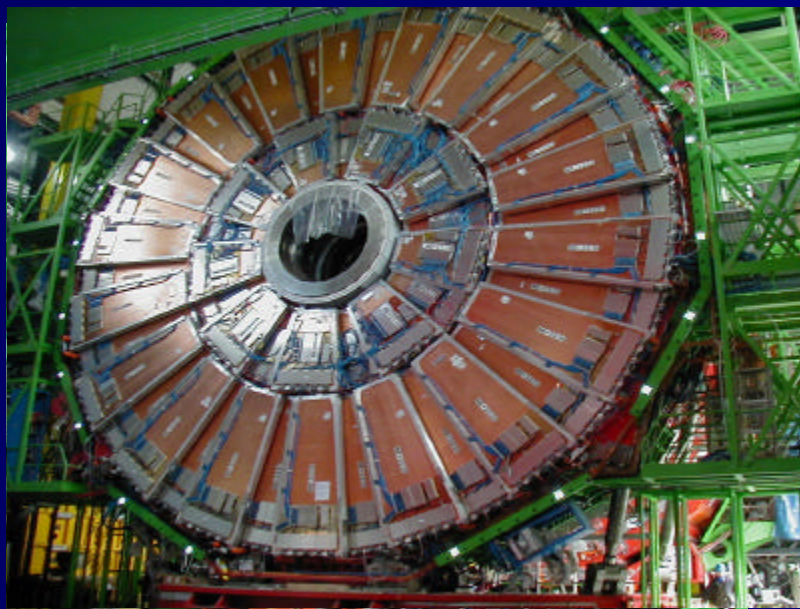
→ position with good resolution (< 100 μm)

In forward region B-field less homogenous than in barrel and higher particle densities
→ cathode strip chambers (CSC)

4 stations (6 layers) for a muon track up to $|\eta| < 2.4$



Status & Performance



Production at 4 sites (FNAL, Beijing, PNPI, Dubna) + testing sites (UC, UF) . 468 CSC's in total.

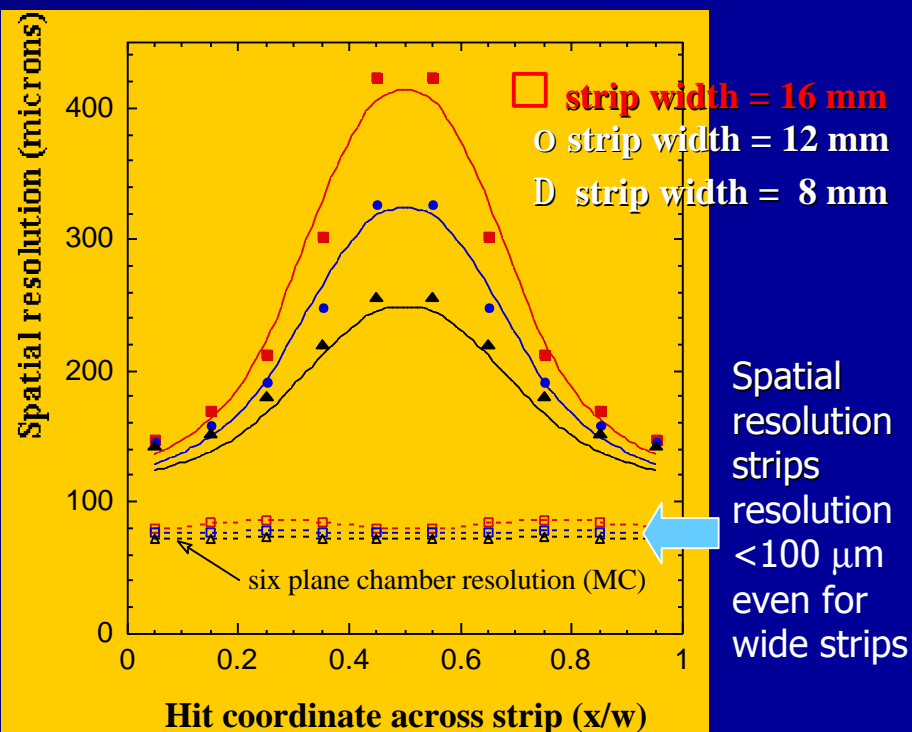
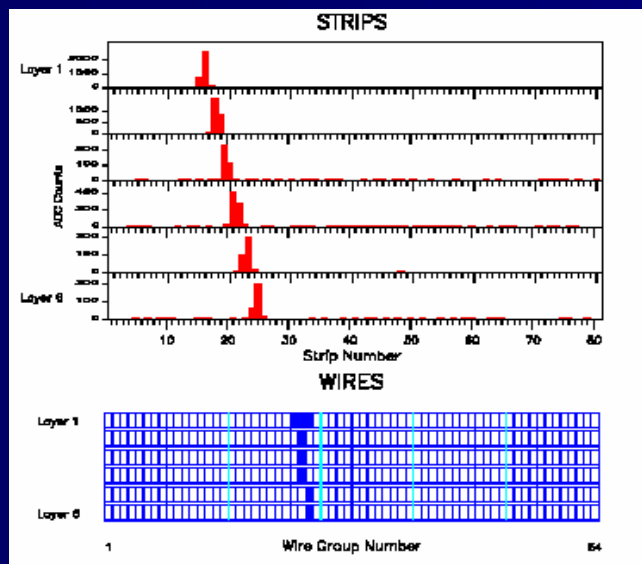
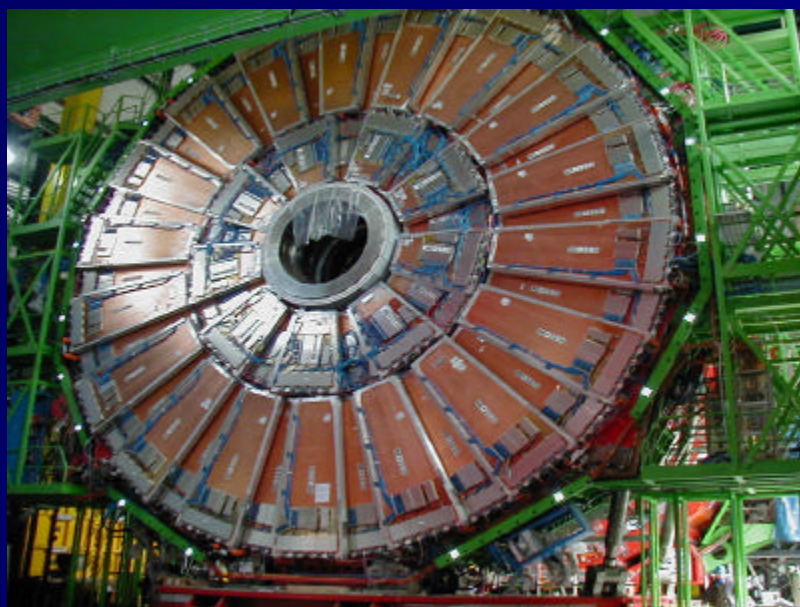
Status in fall 2005:

- Production of chambers and on-chamber electronics completed.
- Off-chamber electronics and HV expected to finish ~beginning 2006.
- All chambers are shipped to Cern.
- Installation according to schedule,

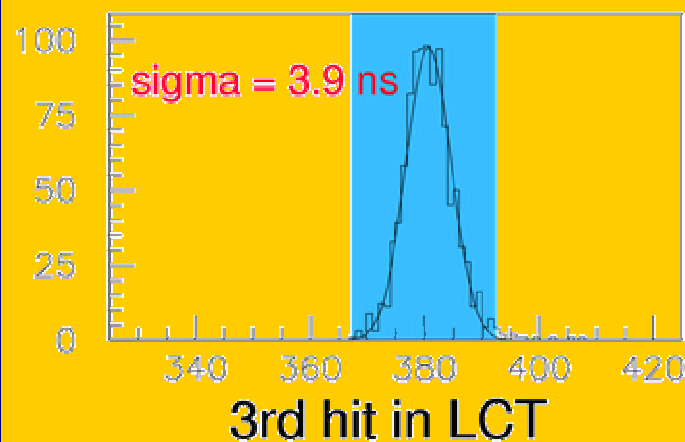
67% of CSC's installed.

- After installation chamber performance tested with cosmic ray tracks. System integration (DAQ, DCS, DQM) ongoing.

Status & Performance

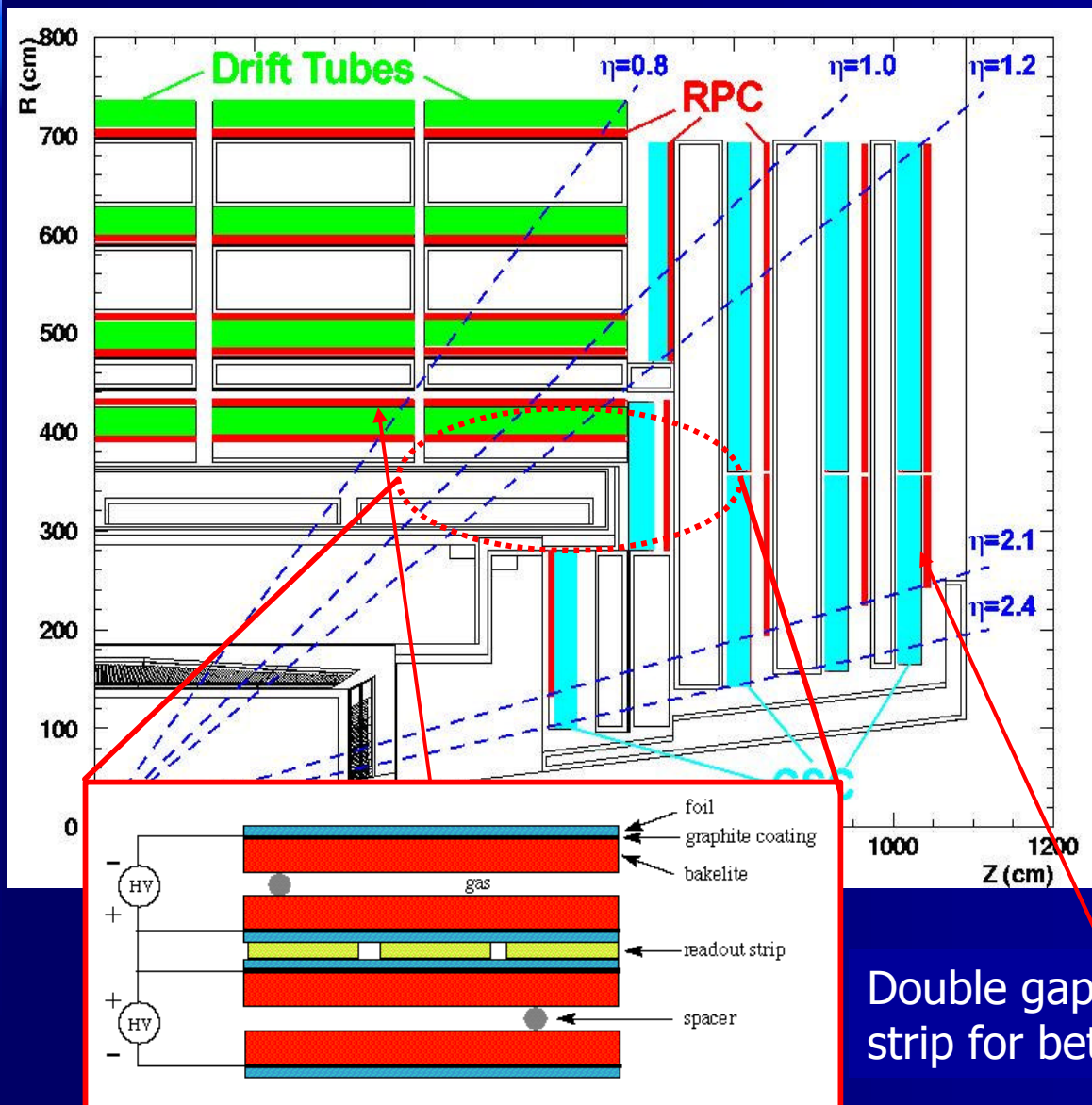


Spatial resolution strips resolution $< 100 \mu\text{m}$ even for wide strips



Fast timing signal from anode wires for BX ID

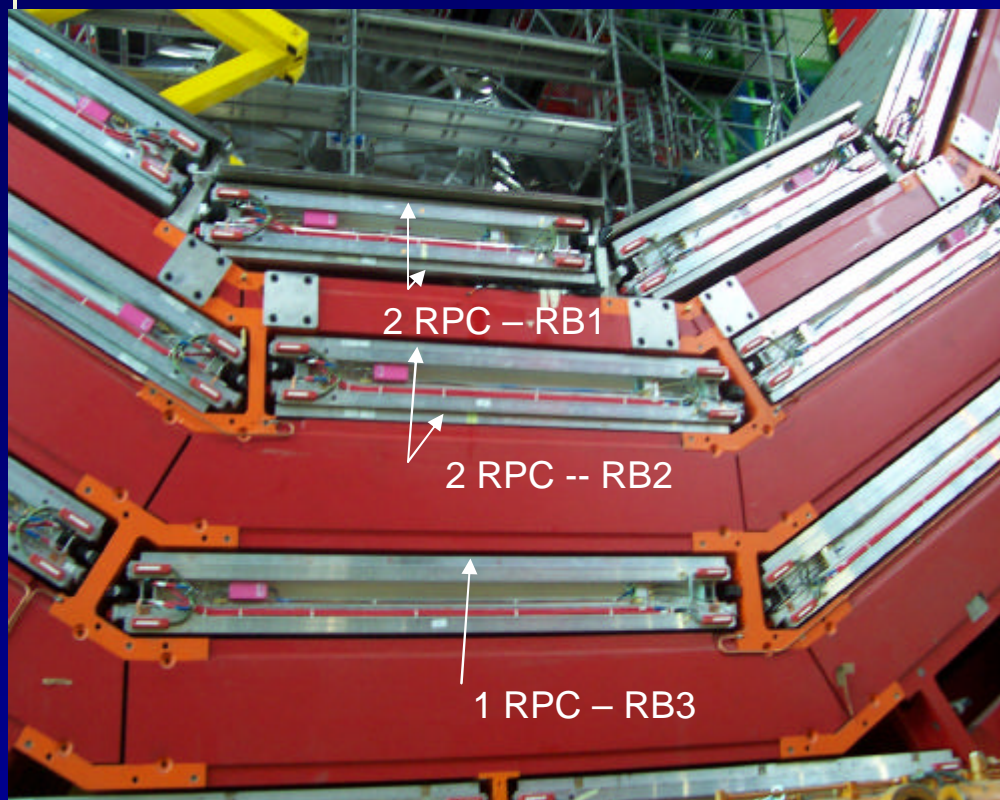
RPCs for Additional Triggering



- 6000 m² (Barrel+EC), ~160 k channels
- 4 Stations with one (outer) or two (inner) RPC
- Redundancy for tracking, dedicated triggering
- Gas: 96.7% TFE, 3% Iso-Butane, 0.3% SF₆

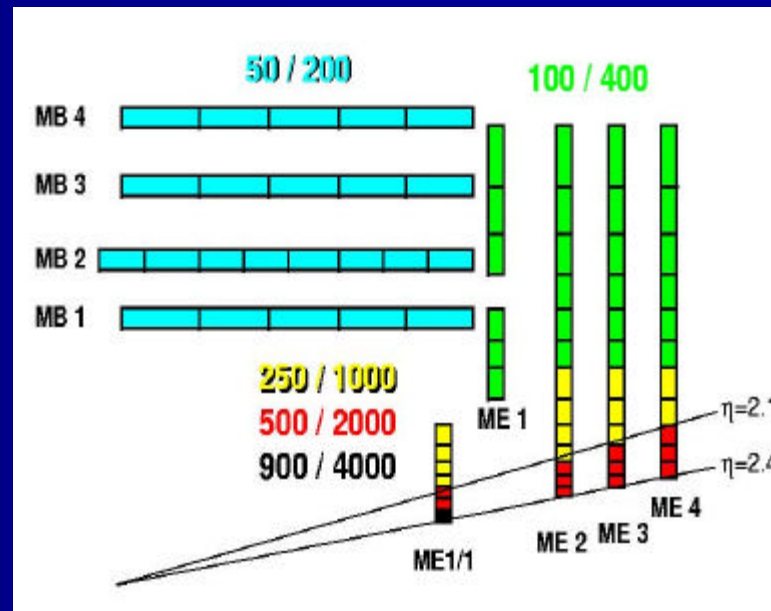
Double gap with single readout strip for better efficiency

Status & Performance



Barrel RPCs are installed packaged together with the DT-chambers.

Forward RPC installation is independent in CSC installation. Has started, according to schedule.



Performance

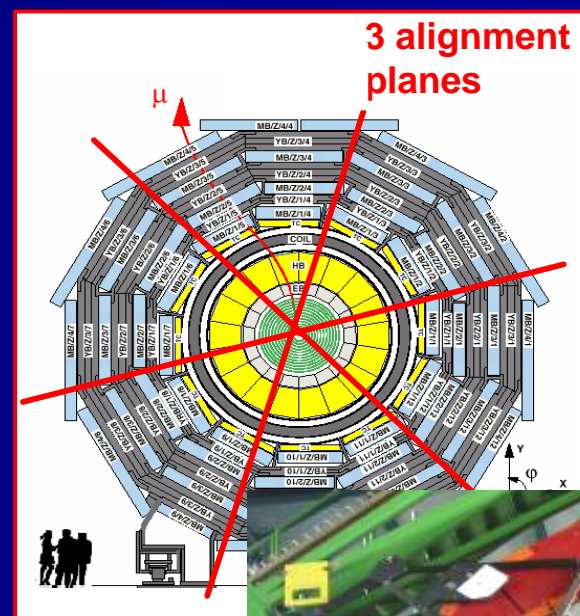
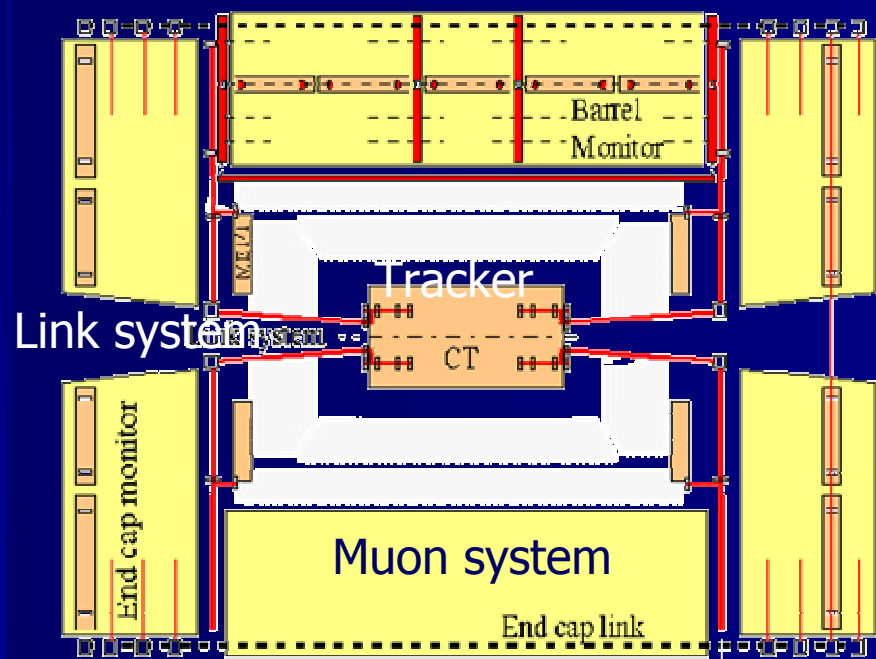
Efficiency	> 95%
Time resolution	< 3ns (98% within 20 ns)
Avg. cluster size	< 3 strips
Rate capability	> 1 kHz/cm ²
Noise rate	< 10 Hz/cm ²
Streamers	< 10%

CMS Alignment System

Tasks of hardware alignment system:

- Measure the relative position of μ -chambers, and w.r.t. to tracker $\leq 100 \mu\text{m}$
- Monitor the stability of tracker $\leq 10 \mu\text{m}$ & muon detectors $\leq 100 \mu\text{m}$

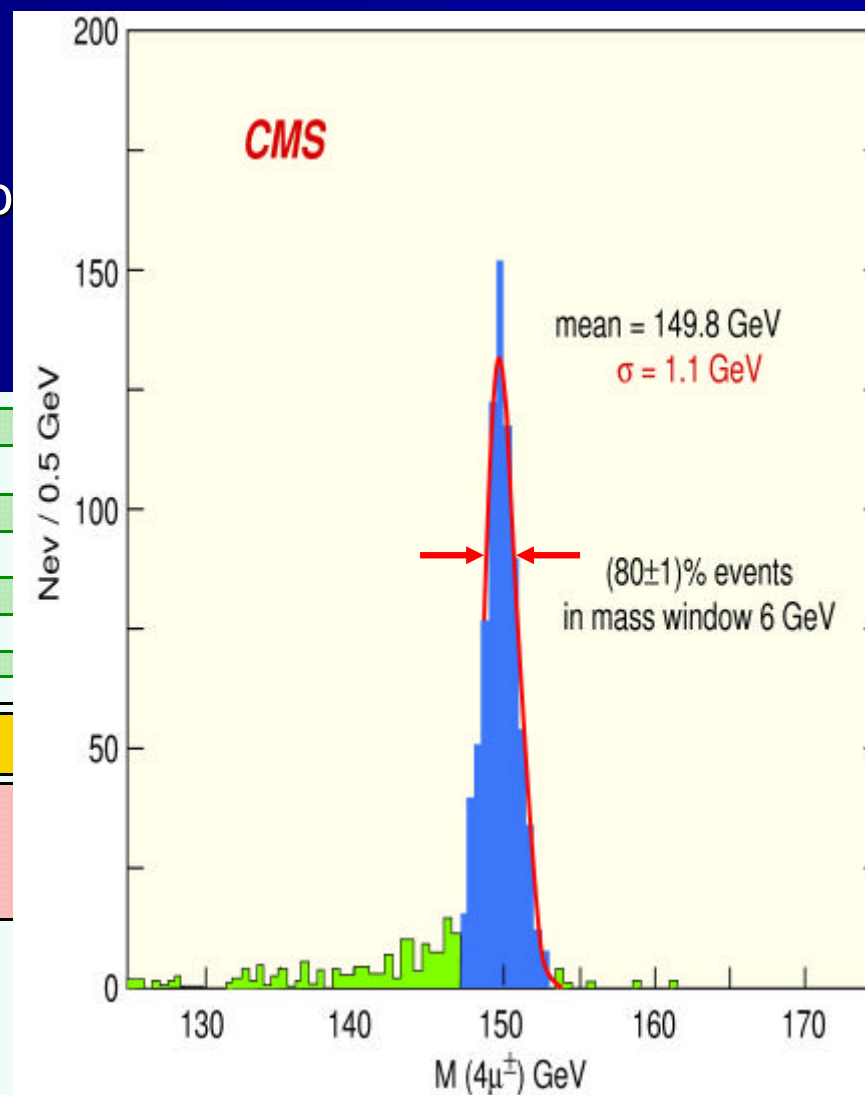
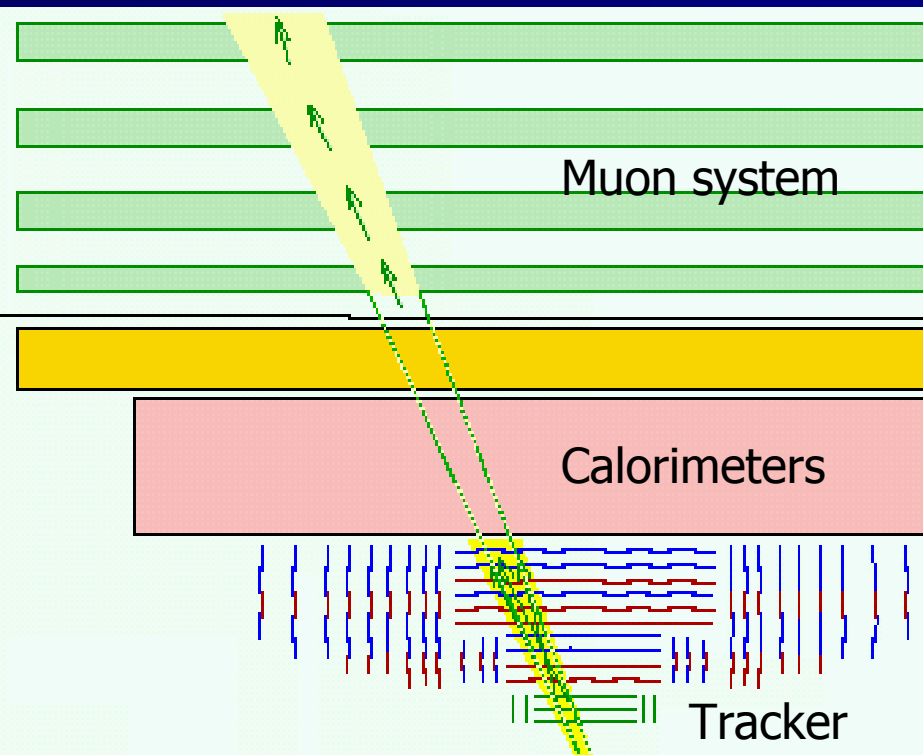
Three building blocks: internal tracker & muon alignment, link muon-tracker



Final precision reached by alignment with tracks, $p_T > 40 \text{ GeV}$ @ $\mathcal{L} = 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
 $\rightarrow \sim 0.1 \text{ Hz/sector}$

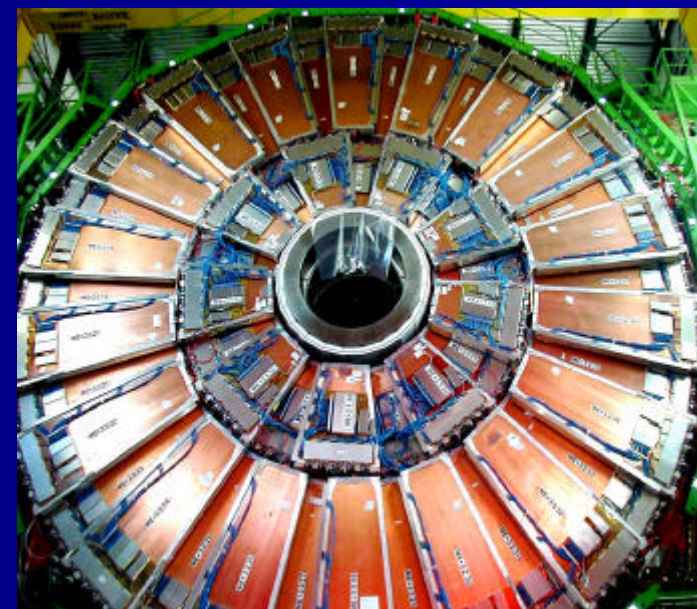
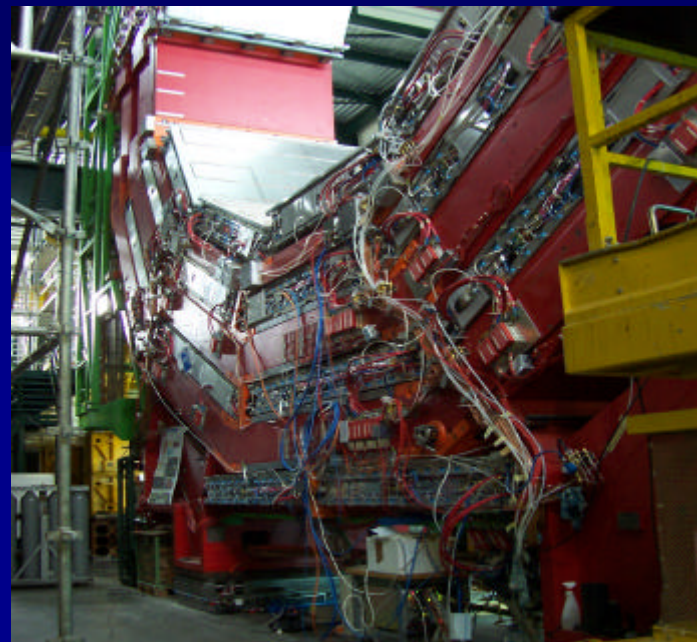
Global Track Reconstruction

1. Segment in Muon system
2. Extrapolate to interaction point
3. Tracker track starts in pixel detector
4. Clean & global refit



Summary

- CMS muon system must **provide 1st level trigger** information and **stand-alone muon momentum** determination (with 1-10% precision) over a wide p_T -range.
- System exploits **3 different detection technologies (DT, CSC, RPCS)** for high efficiency and redundancy.
- Chamber **production** lasted for ~ 4 years, is coming to an end. Installation and commissioning ongoing.
- Detector **performance** studied in testbeams and with cosmics, according to expectation.



Ready for collisions in 2007.....